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**Pulmonary Artery Location During
Microgravity Activity: Potential Impact
for Chest-Mounted Doppler During
Space Travel**

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This study used two subjects and mapped the position of the pulmonary
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ENTER:



PULMONARY ARTERY LOCATION DURING MICROGRAVITY ACTIVITY:
POTENTIAL IMPACT FOR CHEST-MOUNTED DOPPLER DURING SPACE TRAVEL

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ABSTRACT

Doppler, or ultrasonic, monitoring for pain manifestations of decompression sickness (the bends) is accomplished by placing a sensor on the chest over the pulmonary artery and listening for bubbles. Difficulties have arisen because the technician notes that the pulmonary artery seems to move with subject movement in a one-g field and because the sensor output is influenced by only slight degrees of sensor movement. This study used two subjects and mapped the position of the pulmonary artery in one-g, microgravity, and two-g environments using ultrasound. The results showed that the pulmonary artery is fixed in location in microgravity and not affected by subject position change. The optimal position corresponded to where the Doppler signal is best heard with the subject in a supine position in a one-g environment. The impact of this result is that a proposed multiple sensor array on the chest proposed for microgravity use may not be necessary to monitor an astronaut during extravehicular activities. Instead, a single sensor of approximately 1 inch diameter and mounted in the position described above may suffice.

INTRODUCTION

Decompression sickness, as manifested by limb bends, is preceded by the formation of bubbles in tissues and body fluids (refs. 1,4,5,). Although the mechanism of bubble formation has not been elucidated, these bubbles can be detected by a Doppler device located over a vein or the pulmonary artery. Most investigators prefer an aural signal output and the sensor placed over the pulmonary artery (refs. 2,3). A major limitation of the system, however, is the fact that the doppler, or ultrasonic, sensor cannot be mounted on the chest without loss of signal. The reason for this loss of signal is twofold. First, the target area is at the heart, and therefore, the pulmonary artery moves during physical activity and with different postures. Secondly, the sensor is quite sensitive. Even very small manipulations of the ultrasonic device can result in a marked reduction of signal quality.

An obvious advantage to having a stable chest-mounted sensor, one whose signal quality is unaffected by movement, is that Doppler bubble monitoring could be provided during the normal extravehicular activities occurring in space flight. It was our intention and the purpose of this study to provide basic data concerning pulmonary artery location during microgravity exposure. The knowledge gained could then be applied to proper sensor design.

MATERIALS AND METHODS

Two healthy adult males, with less than 10% body fat, gave informed consent to participate in this study. In the standard one-g environment both subjects had a model 1032 portable Doppler sensor device¹ with a single transmit (5 MHz) and receive crystal placed on their chest. The pulmonary valve was located, as evidenced by a distinct "whipping" sound, in the supine, standing, sitting, left lateral decubitus, and right lateral decubitus positions (fig. 1). In all instances, an area of acceptable signal was established, and an

1. Model 1032G Doppler Bubble Detector. Insti. of Appl. Physiol. and Med., Seattle, Washington.

ink line was used to demarcate the various positions of signal acceptability. With these ink lines still in place, the subjects then boarded the NASA KC-135 aircraft, which is routinely used to fly microgravity parabolas. In both subjects the zones of signal acceptability were verified for the anatomic positions described above. During the microgravity phase of the flight, the optimum Doppler signal was again established for the supine, standing, sitting, left and right lateral decubitus, as well as for the prone position. These areas were outlined for signal acceptability using ink. At the conclusion of the mapping of the various anatomic positions, the Doppler sensor was affixed to the chest, using doublesided adhesive tape, at a location that was identical to the subject's supine Earth-based location. The subject was then allowed to free float through the cabin during the microgravity maneuvers and Doppler recordings were collected. Next, for comparison, the right and left lateral decubitus were surveyed using the Doppler device during the two-g phases of the flight. The area of optimal signal acceptability was recorded (fig. 1). All Doppler recordings were placed on analogue tape for subsequent reverification of signal quality.

RESULTS

It is apparent from fig. 1 that in the normogravic and hypergravic situations, signal quality from our Doppler device was influenced by position of the subjects. This fact is explained as the heart, and hence the pulmonary artery, is able to move freely in the chest and can be influenced by gravity loading. With the subject in the right lateral decubitus position, an acceptable signal was difficult to attain. However, during the two-g phase of the flight, a signal was obtained clearly at position five. Note that there was significant individual variation with the optimization of signal in the one-g environment.

Significantly, when the subjects were placed in the supine, standing, sitting, right lateral decubitus, or prone position and then exposed to microgravity, the signal from the Doppler was best heard at position 1. This position corresponds to the point where the signal optimization occurred in the supine position in normogravic conditions. Yet, in the left lateral decubitus position, the pulmonary artery was not heard best at position 1 but rather at position 4, which is an exception to the results noted above.

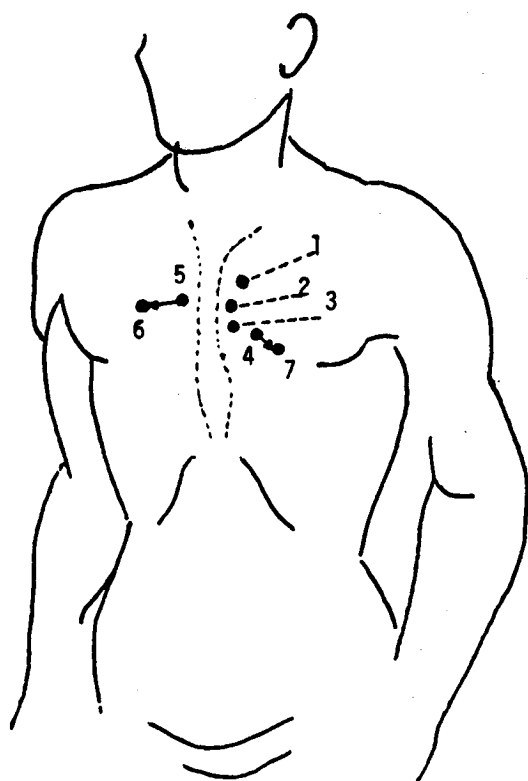
When the sensor was affixed to the chest at position 1, the normogravity position where the signal is best heard in the supine position, and the subject allowed to free float and perform various spins, flips, and other acrobatic maneuvers, a quality signal was maintained no matter what activity the subject performed during microgravity exposure. Like normogravic conditions, signal quality could be lost if the subject inhaled too deeply or if he moved his arms in such a fashion to cause chest wall movement, which in turn, physically displaced the sensor from the pulmonary artery.

Two positions, the left and the right lateral decubitus, were examined in the hypergravic two-g condition. The pulmonary artery was displaced downwards and to the left in the left lateral decubitus position and to the right in the right lateral decubitus.

CONCLUSION

Doppler evaluation during extravehicular activities has not been performed to date. One of the reasons is that signal quality is extremely sensitive to sensor placement and to subject positioning. Subject positioning matters because when a subject moves, so does his pulmonary valve, the area over which Doppler monitoring for premonitory signs of decompression sickness is accomplished. This study, albeit limited with regard to number, represents the first attempt to locate the pulmonary valve during differing anatomical positions in a microgravity environment and contrasting those with a normogravic environment. As mentioned above, the pulmonary artery is affected by position in a one-g environment and by gravity loading. However, in a microgravity environment, the Doppler signal optimization, and hence, pulmonary valve localization, occurred at all times at position 1. This position corresponded to where the signal was best heard in a one-g environment in a supine position. Furthermore, when the Doppler transducer was placed over this position, affixed to the skin by means of double-sided adhesive tape, and the subject allowed to free float in microgravity, the subject could be monitored continuously. One exception to this rule was if the subject was placed in the left lateral decubitus position. The best signal from the Doppler was now heard in position 4 (fig. 1). This position also gave the best signal in a one-g environment. Thus, if the heart was displaced to the left by the subject's original position, it tended to remain there during subsequent microgravity exposure. Yet, if the heart was displaced to the right, subsequent microgravity exposure revealed that the pulmonary artery was best heard by Doppler on the left side of the sternum at position 1.

In summary, we found that the position of the pulmonary artery to be remarkably stable under microgravity conditions. The implications of this finding are directed to those studying the phenomenon of limb bends. It may be possible now to design a single chest-mounted sensor rather than have sensor arrays on the chest. The position of this sensor should be at position 1, the position where the best Doppler signal is heard under normogravic conditions, with the subject in the supine position. Doppler coverage of a subject's movements during microgravity maneuvers was optimal in this location.



1. supine
2. standing
3. sitting
4. left side
5. right side
6. right displacement
during two-g
7. left displacement
during two-g

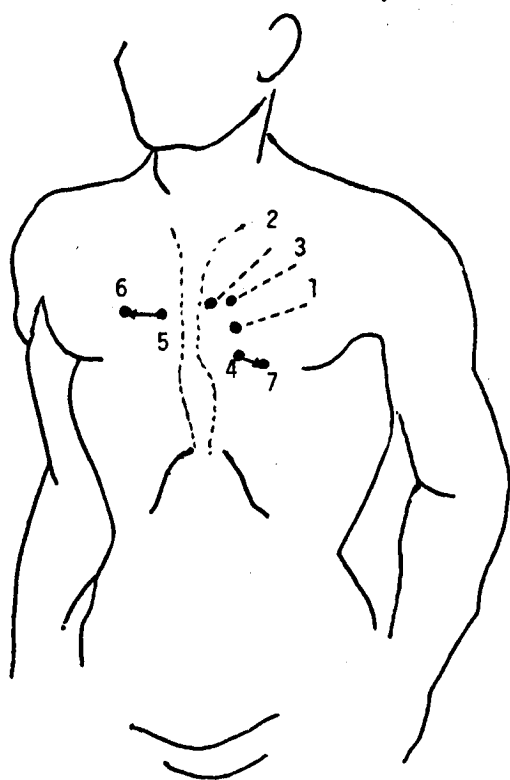


Figure 1. Optimum sensor location on two subjects during one-g and two-g phase of flight. During zero-g phase heart stayed at position 1 despite active movement in zero-g.

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